ARTÍCULO DE INVESTIGACIÓN CIENTÍFICA

Sociedad Colombiana
de la Ciencia del Suelo

GERMINACIÓN Y DESARROLLO DE *Jatropha curcas L.* ETAPA DE VIVERO EN DIFERENTS ESTRATOS EN SANTA MARTA MAGDALENA

Sonia Aguirre Forero[1] ✉, Nelson Piraneque Gambasica[2]

[1] Doctor of Agricultural Sciences, Professor, Universidad del Magdalena, Santa Marta, Colombia.
✉: saguirre@unimagdalena.edu.co.
[2] Doctor of Agricultural Sciences, Professor, Universidad del Magdalena, Santa Marta, Colombia

Palabras clave:
Jatropha curcas, euphorbiaceae, cultivos oleaginosos, germinación de semillas, plántulas.

RESUMEN

La germinación es una de las etapas más vulnerables en el ciclo vital de las especies, por lo que el sustrato debe estar en capacidad de suministrar la humedad, el oxígeno, la luz y los nutrientes necesarios para que este proceso culmine de forma adecuada. En Santa Marta, Magdalena Colombia entre enero y diciembre de 2013, se evaluó el efecto del sustrato sobre la germinación y desarrollo de semillas de Jatropha curcas en condiciones de vivero. Se establecieron 10 tratamientos en un arreglo completo al azar: suelo, arena, cascarilla de arroz y turba solos y en mezcla en relación 1:1 con 50 repeticiones a los que se determinó: días a inicio de germinación, porcentaje de emergencia, día pico con mayor cantidad de plántulas emergidas y valor de germinación (VG). Luego, con los sustratos que superaron 65% de germinación, se valoró: altura de plántula, largo del sistema radical, biomasa radical y aérea, masa seca de raíces y aérea y diámetro basal del tallo. Los resultados permitieron determinar que los tratamientos 1, 7, 9 y 10 mostraron mayor eficiencia en el proceso de germinación con 72, 66, 70 y 94%, respectivamente. La máxima germinación (94%) obtenida en T10, se correspondió con la mayor velocidad y VG (22,65), evidenciando condiciones aptas del sustrato para la emergencia de plántulas. T7 superó en altura, diámetro y fitomasa a los demás tratamientos. Suelo, Cascarilla+turba, Arena+Turba y Suelo+Turba, son los sustratos que potencializan el valor de la germinación de J.curcas en condiciones de vivero y ambientales del Magdalena.

GERMINATION AND DEVELOPMENT OF *JATROPHA CURCAS* L. NURSERY SEEDLINGS IN DIFFERENT SUBSTRATES SANTA MARTA MAGDALENA.

Key words:
Jatropha curcas, euphorbiaceae, oil crops, seed germination, seedlings

ABSTRACT

Germination is one of the most vulnerable stages in the life cycle of a species, so the substrate must be able to supply moisture, oxygen, light and nutrients necessary for to complete this process. The germination and development of Jatropha curcas seeds in different substrates were evaluated in the Santa Marta municipality of Magdalena, Colombia, between January and December in 2013 utilizing a completely randomized design in which ten treatments were established: soil, sand, rice husk, peat and the mixture of these. Variables evaluated were days to germination, emergence percentage, peak day seedling emergence, and germination value (VG). Then, with the substrates that exceeded 65% germination; seedling height, length of root system, root and air fresh mass, root and air dry mass, and basal stem diameter were assessed. Our results determined that treatments 1, 7, 9 and 10 showed greater efficiency in the germination process; with 72, 66, 70, and 94% germination, respectively. The maximum germination (94%) obtained in T10, corresponded with greater speed and VG (22.65), indicating suitable substrate conditions for seedling emergence. T7 surpassed the others treatments in height, diameter, and biomass. Soil, rice husk+peat, sand+peat, and soil+peat were the substrates that are most highly indicated to increaseJ. curcas germination values in nursery and environmental conditions of Magdalena, Colombia.

SUELOS ECUATORIALES
45 (2): 48-54

ISSN 0562-5351

Rec.: 01.08.2015
Acep.: 20.10.2015

INTRODUCTIÓN

Biofuels are an option to partially replace fossil fuels (Koh & Mohd. Ghazi, 2011; Openshaw, 2000), in order to reduce the emission of pollutants. Jatropha (*Jatropha curcas* L.) (Greek jatrós=doctor and trophe = food) is an oleaginous plant with multiple beneficial attributes native to Mexico (Rucoba García, Munguía Gil, & Sarmiento Franco, 2013) that has achieved importance in Colombia due to its production adaptability and quality of oil for biofuels. Thus, it has stimulated research in physiological and productive behavior (Pedraza S. Erik & Cayón S. D., 2010) in different agro-ecological zones. The Colombian Caribbean region has suitable agro-ecological conditions for the cultivation of *Jatropha curcas*, which gives it the potential to be a leader in biofuel production in both Latin American and around the world (Agudelo, A & Benjumea, P, 2008); Horta, 2004); (La República, 2013). However, even though *Jathropa* provides sub-products that are used at the industry level in both the medical and pest control areas (Galaz-Ávalos, Rosa, Avilez-Montalvo, R, Ucan-Uc, C., Chan-López, J, & Loyola-Vargas, V, 2012), knowledge of the agronomic behavior of this species is incipient (Patel & Saraf, 2013; Abhilash, Singh, Srivastava, Schaeffer, & Singh, 2013).

The development of the biofuels industry, offers the opportunity to exploit comparative advantages that Colombia has as a tropical country in comparison with other agricultural areas; it also constitutes a scientific and technological challenge to the academic community, who working in conjunction with the productive sector, in order to achieve developments that improve and sustain the capacity of soils without compromising food security, thus converting it into a factor of social equity (Funez, E., Arévalo, E., Pack, G, & Quezada, J., 2009). In this regard, *J. curcas* is a perennial, drought tolerant, rustic plant known for its bioremediation effects (Contran et al., 2013; Singh et al., 2013) in devastated areas which adapts well to different edaphoclimatic conditions to meet these challenges (Singh et al., 2013; Sotolongo Pérez, J. et al., 2007). The adaptability of *Jathropa* is related to the formation of the root system, which is usually influenced by the method of propagation of the species: Asexually, these plants accelerate their vegetative period and reduce genetic variability; while through the use of seeds, they retain the characteristics of rusticity and their root structure, allowing them greater adaptation to the environment (Empresa Brasilera de Pesquisa Agropecuaria -EMBRAPA, 2013).

However, producers of this species have had different experiences in different territories, leading to different views of its utility. Ariza-Montobbio and Lele (2010), showed that in India, 30% of *J. curcas* plantations in monoculture were removed and 50% abandoned shortly after its establishment due to cross-pollination. The species spreads rapidly due to cross-pollination, which brings a high degree of variation allowing it to adapt to different conditions; however, this characteristic is also reflected in diversity and quality of seed oils, in time of flowering, and, in male and female flower relationship (Rucoba García et al., 2013); which are undesirable characteristics as productive parameters for biodiesel. Root system formation is similarly influenced by the method of propagation of the species.

King et al. (2013) and Rodríguez-Acosta, Vega-Flores, Gante-Cabrera, Hugo, & Jiménez-Ramírez (2009) ensure that techniques for breeding and management that expand the range of seed uses are necessary. Therefore, it is necessary to study and develop of techniques that allow us to obtain more information on each crop phenological stage to achieve production sustainability (Pedraza S. Erik & Cayón S. D., 2010) in the Colombian Caribbean region.

In this direction, Mantilla, A, (2003) defines germination as the set of metabolic and morphogenetic processes that result in the transformation of an embryo into a seedling able to fend for itself because it is photosynthetically competent. Germination is thus one of the most vulnerable processes that occur within a plant's life cycle because the development of new generations of a species depends on it. Within this context; sufficient and continuous moisture, proper temperature, periods of light-dark, oxygen, and *substrate* are required for seeds to germinate. In the first stage of the germination process, the seed uses only nutrients contained in its storage tissues (cotyledons and endosperm), therefore, during this time, it is required that the substrate has the ability to maintain adequate moisture, to permit the entry of oxygen and light, and to prevent the sun's rays from falling directly onto the seed. But, when the seedling develops photosynthetically active leaves and roots with the ability to absorb nutrients, the substrate must contain suitable quantities of macro and micro elements for the normal nutrition and development of plant material (Salinas, Yoldjian, Craviotto, & Bisaro, 2001).

In this regard, it should be noted that there is a direct relationship between substrate and germination percentage, demonstrated by practical results of tests of vigor relating to field emergence and seed storage potential, which could also relate to greenhouse emergence and seedling growth (Djavanshir, K. & Pourbeik, H., 1976). Therefore, two batches of seeds with the same germination levels may behave differently under the same field conditions. Thus, it follows that substrates are a vital factor in the germination process.

Considering the growing interest in the biofuels industry for *J. curcas* and lack of information on the germination process, this investigation determined the germination and development of *J. curcas* seedlings established in different substrates under nursery conditions in Santa Marta, Magdalena, Colombia.

MATERIALS AND METHODS

This investigation was conducted at the Center for Agricultural and Forestry Development (CDAF) at the University of Magdalena, Santa Marta, Colombia: geographic coordinates 74º 11' 5.33" west longitude and 11º 13' 28.98" north latitude, Holdridge classification: Tropical Thorn Forest (TTF), 21 m.a.s.l and 28°C mean annual temperature (Instituto Geográfico Agustín Codazzi - IGAC, 2009).

Brazillian *J. curcas* seeds from a 1.5 year-old crop, were obtained manually from the fruit 15 days after harvested, were exposed to direct sunlight after checking their health status, stored at room temperature in polyethylene bags in the CDAF, and were then planted directly, individually, and horizontally in 500 black polyethylene bags pre-filled with substrate with dimensions of 25 cm x 30 cm x 15 cm. Peat (Pindstrup Plus peat substrate), CDAF soil, river sand, and rice husk were used for the preparation of substrates. Irrigation was performed manually twice a day. The substrates including double associations were prepared in 1:1 ratios by manually mixing the material until their distribution was uniform. The treatments (Table 1) were evaluated in complete randomized design blocks: ten treatments with 50 repetitions, for a total of 500 experimental units of *J. curcas* plants, were established. Treatments corresponded to four individual substrates and six double associations in 1:1 ratios.

Table 1. Treatments evaluated.

TREATMENT	DESCRIPTION
T1	Soil (pH: 7.82; CE:1.55 dSm^{-1}; Da: 1.3 g cm^{-3})
T2	Sand
T3	Rice husk
T4	Peat (pH: 4; CE 0,4 dSm^{-1}; Da: 0,48 g cm^{-3})
T5	Soil+Sand (1:1)
T6	Soil+Rice husk (1:1)
T7	Soil+Peat (1:1) (pH: 7.81; CE: 0.945 dSm^{-1}; Da: 1g cm^{-3})
T8	Sand+Rice husk (1:1)
T9	Sand+Peat (1:1) (pH: 7.67; CE: 0.625 dSm^{-1}; Da: 1g cm^{-3})
T10	Rice husk+ Peat (1:1) (pH: 6.88; CE: 0.12 dSm^{-1}; Da: 1g cm^{-3})

In the first phase, **Germination Percentage (PG)** was evaluated during 30 days immediately after sowing the seeds. To obtain PG, the total number of germinated seeds was divided by the total number of seeds sown and multiplied by 100. **Germination Value** was determined by identifying the following values:: Days until start of emergence –IE—, Final emergence percentage for test period –Emer—, Peak day: in which the largest quantity of seedlings was observed –DP—, Emergence peak: maximum percentage of emergence observed in the same day –EP— (Association of Official Seed Analysis AOSA, 2000), and Germination value (VG), determined through the use of the formula proposed by (Djavanshir, K. & Pourbeik, H., 1976) (equation 1) , in that the test was performed in greenhouse conditions over land and environmental conditions that were not controlled.

$$VG = \left(\sum VGD/N\right) * {PG}/{10} \quad \mathbf{(1)}$$

Where:

VG = Germination Value

PG = Germination percentage at end of test

VGD = Daily germination rate, obtained by dividing the cumulative germination percentage by the number of days since sowing

ΣVGD = Total obtained by summing all VGD figures obtained by daily counts

N = Number of daily counts, beginning from the date of first germination.

In the second phase, physiological parameters were evaluated on treatments which exceeded 65% germination, and for five weeks, consistent samples of six seedlings per treatment for a total of 30 plants were evaluated, measuring: number of leaves -NH-, seedling height -h- (cm), length of root system -LR- (cm), biomass of root system -BR- (g), air biomass -Bf- (g), air dry mass -Msf- (g), root dry mass -Msr- (g), and basal stem diameter -Dt- (cm). These variables were selected for their reciprocity to the expression of vigor and quality of the germination process. The relationship is based on how they describe and characterize the performance of the seeds in actual planting conditions. They also allow for the estimation of potential seedling emergence in the field, taking into account the inevitable effect of environmental conditions. Analysis of variance (ANOVA) and Spearman multiple correlation analysis (to determine the association between the physiological variables studied) were utilized to analyze the data and the Tukey comparison test (0.5%) was used on those that showed difference. R version 2.11.1 (R Development Core Team 2010 available www.r-proyect.org) was used for statistical analysis.

RESULTS

First phase: Germination and seedling emergence. Table 2 summarizes the data obtained, showing that the maximum percentage of germination was obtained in T10 (Pr <0.001), followed by T1, T9, and T7 with 94%, 72%, 70% and 66%, respectively, substrates were selected to continue in the second phase of the experiment. Rice husk substrate showed the lowest percentage of germination, possibly due to its low capacity for water storage (Huacuja, 2009; Alvarado, M. Solano, J, 2002) under the environmental conditions of the area. In standard germination tests, seed are placed in the laboratory under ideal conditions of light and temperature to induce germination, but when they are taken to the field, they are exposed to different parameters. Isely (1958) defines vigor as "the sum total of all the attributes of the seed that favor rapid and uniform seedling establishment in the field". Thus, the vigor of *J. curcas* seeds were determined and used to estimate the possible behavior of future plants in the field. In this sense, germination in those seeds that showed above 80% (T10) were classified as high vigor, those between 60-80% (T1, T9 and T7) were classified as medium vigor, and those under 60%, were classified as low vigor (Salinas et al., 2001; Tekrony, D. M, 1995).

Table 2. Germination Value Calculations.

TREATMENT	EMER	IE	DP	PDP	EP	TPG	UDG	∑ VGD	N	∑ VGD/N	VG
T1	72^{b}	7^{c}	19^{ns}	5^{ns}	10	31^{b}	24^{bc}	35.64^{c}	18^{a}	1.98^{b}	14.26^{b}
T2	52^{d}	6^{c}	17^{ns}	4^{ns}	8	26^{d}	23^{bc}	22.34^{d}	18^{a}	1.24^{d}	6.45^{cd}
T3	12^{e}	15^{a}	18^{ns}	3^{ns}	6	6^{e}	18^{c}	1.4^{f}	4^{b}	0.35^{d}	0.42^{cd}
T4	44^{d}	7^{c}	19^{ns}	4^{ns}	8	22^{d}	20^{c}	16.56^{e}	14^{a}	1.18^{d}	5.21^{cd}
T5	52^{d}	6^{c}	20^{ns}	4^{ns}	8	26^{d}	25^{bc}	23.76^{d}	20^{a}	1.19^{d}	6.18^{cd}
T6	52^{d}	6^{c}	18^{ns}	5^{ns}	10	26^{d}	26^{bc}	29.24^{cd}	21^{a}	1.39^{d}	7.24^{cd}
T7	66^{c}	7^{c}	17^{ns}	5^{ns}	10	33^{c}	29^{a}	40.91^{b}	23^{a}	1.78^{c}	11.74^{c}
T8	50^{d}	6^{c}	18^{ns}	4^{ns}	8	25^{d}	24^{bc}	21.27^{d}	19^{a}	1.12^{d}	5.6^{d}
T9	70^{c}	8^{c}	16^{ns}	4^{ns}	8	35^{c}	29^{a}	37.83^{c}	22^{a}	1.72^{c}	12.04^{c}
T10	94^{a}	11^{b}	19^{ns}	6^{ns}	12	47^{a}	29^{a}	45.79^{a}	19^{a}	2.41^{a}	22.65^{a}

Means with the same letter do not differ significantly (Tukey, P ≤ 0.05). ns = Not significant.

The Spearman correlation shows high significance (P ≤ 0.05) in the association between all variables evaluated. Thus, NH correlates positively with all other variables, including h, Bf, and Msf, which show the greatest association to it (r = 0.79, r = 0.72, and r = 0.69, respectively). In turn, h correlates positively with all variables, but Msf, Bf, Msr, Dt, and BR, show the greatest association with it (r = 0.8404, r = 0.8402 r = 0.753, r = 0.751 and r = 0.744, respectively). For its part, Dt correlated positively with Bf, BR, Bsf, and Bsr and it was also observed that as the roots grew, stems increased in diameter (r = 0.799). Finally, Bf was closely related to BR, LR, Msf, and Msr, suggesting the importance of the root system for plant nutrition (Mantilla, A, 2003; Bertsch, Floria, 2000) and seedling development.

It follows that the higher values of dry matter obtained by T7 (Soil + Peat), probably indicate that it provided the best conditions for seedling development. In this regard, Pedraza & Cayón, (2010) and Nakagawa (1999), stated that the determination of dry matter is one way to evaluate the growth of seedlings which can accurately determine the transfer of cotyledonary reserves to the embryo, in that the samples with more dry matter are considered to have greater vigor; a condition that was supported in this study.

CONCLUSION

From our studies it can be concluded that the germination process of *J. curcas* presented different behavior depending on the substrate tested, with Rice husk + Peat, Soil, Sand + Peat, and Peat + Soil showing the greatest efficiency in the germination process; with 94, 72, 70, and 66%, respectively. This demonstrated their superior nutritional inputs and physical conditions for initiating the process of germination and seedling development.

The vigor of *J. curcas* seed was measured based on germination value (VG), which combines different parameters such as germination percentage and speed to obtain a measurement that reflects the ability of germinated seedlings to be transplanted in the field. Thus, Soil, Rice husk + Peat, Sand + Peat, and Soil + Peat are the substrates that enhance the value of germination of the species under both nursery conditions and the environmental conditions found in Colombia's Magdalena region.

T7, (Soil + Peat) showed the highest values for physiological characteristics evaluated, suggesting nutritional inputs and better aerodynamic conditions of the substrate which facilitated the germination process, the high vigor obtained and, in general terms, the best seedling development of all trials.

REFERENCES

ABHILASH, P. C., SINGH, B., SRIVASTAVA, P., SCHAEFFER, A., & SINGH, N. (2013). Remediation of lindane by Jatropha curcas L: Utilization of multipurpose species for rhizoremediation. Biomass and Bioenergy, 51, 189–193. doi:10.1016/j.biombioe.2013.01.028

AGUDELO, A, A., J., & BENJUMEA, P. (2008). Diagnóstico exergético del proceso de combustión en un motor Diesel, 45, 41–53.

ALVARADO, M. SOLANO, J. (2002). Producción de sustratos para viveros. San José de Costa Rica: Vifinex. Retrieved from http://www.croprotection.webs.upv.es/documentos/Compostaje/Sustratos-para-Viveros.pdf

ARIZA-MONTOBBIO, P., & LELE, S. (2010). Jatropha plantations for biodiesel in Tamil Nadu, India: Viability, livelihood trade-offs, and latent conflict. Ecological Economics, 70(2), 189–195. doi:10.1016/j.ecolecon.2010.05.011

AOSA. (2000). Rules for testing seeds (Vols. 1-4, Vol. 2). Washington, DC: AOSA. Retrieved from http://www.aosaseed.com/aosa_rules_for_testing_seeds

BERTSCH, FLORIA. (2000). La fertilidad de los suelos y su manejo (1a ed.). San José de Costa Rica: ACCS. Retrieved from http://www.ipni.net/ppiweb/ltamn.nsf/$webindex/4682F9448322F81905256B910018F071?OpenDocument&navigator=publicaciones+disponibles

CONTRAN, N., CHESSA, L., LUBINO, M., BELLAVITE, D., ROGGERO, P. P., & ENNE, G. (2013). State-of-the-art of the Jatropha curcas productive chain: From sowing to biodiesel and by-products. Industrial Crops and Products, 42, 202–215. doi:10.1016/j.indcrop.2012.05.037

DJAVANSHIR, K. & POURBEIK, H. (1976). Germination Value - a new formula. Silvae Genetica, 25(2), 79–83.

EMBRAPA. (2013). Formação do Sistema Radicular de Plantas de Pinhão Manso Propagadas por Mudas, Estacas e Sementes. EMBRAPA. Retrieved from http://ainfo.cnptia.embrapa.br/digital/bitstream/CNPA/20249/1/COMTEC348.pdf

FUNEZ, E., ARÉVALO, E., PACK, G, & QUEZADA, J. (2009). Comparación de sustratos para la siembra de piñón (Jatropha curcas) en etapa de vivero finca Santa Lucía, Choluteca, Honduras. CEIBA, 50(2), 58.

GALAZ-ÁVALOS, ROSA, AVILEZ-MONTALVO, R, UCAN-UC, C., CHAN-LÓPEZ, J, & LOYOLA-VARGAS, V. (2012). Jatropha curcas una Alternativa para la Obtención de Biodiésel sin Afectar al Sector Alimentario. Biotecnología, 16(2), 94–114.

HORTA, L. (2004). Perspectivas de un programa de biocombustibles en América Central: Proyecto Uso Sustentable de Hidrocarburos (Convenio CEPAL. Comisión Económica para América Latina y el Caribe. Retrieved from http://www.cepal.org/es/publicaciones/25669-perspectivas-de-un-programa-de-biocombustibles-en-america-central-proyecto-uso

HUACUJA, V. (2009). Evaluación de sustratos para la producción de plántulas de tomate de cáscara (Physalis ixocarpa Brot) bajo invernadero, en Zamora, Michoacán (Tesis de pregrado). Universidad Michoacana de San Nicolas de Hidalgo, Michoacán. Retrieved from http://bibliotecavirtual.dgb.umich.mx:8083/jspui/bitstream/123456789/441/1/EVALUA~3.PDF.

IGAC. (2009). Estudio general de suelos y zonificación de tierras Departamento del Magdalena (IGAC, Vols. 1-1, Vol. 1). BOGOTA.

ISELY, D. (1958). Testing for vigor. Proc.Assoc. Off. Seed Anal, 48(1), 136–138.

KING, A. J., MONTES, L. R., CLARKE, J. G., AFFLECK, J., LI, Y., WITSENBOER, H., … GRAHAM, I. A. (2013). Linkage mapping in the oilseed crop Jatropha curcas L. reveals a locus controlling the biosynthesis of phorbol esters which cause seed toxicity. Plant Biotechnology Journal, 11(8), 986–996. doi:10.1111/pbi.12092

KOH, M. Y., & MOHD. GHAZI, T. I. (2011). A review of biodiesel production from Jatropha curcas L. oil. Renewable and Sustainable Energy Reviews, 15(5), 2240–2251. doi:10.1016/j.rser.2011.02.013

LA REPÚBLICA. (2013, Abril de). Colombia sería segundo productor de biocombustibles. Diario La República. Bogotá D.C. Retrieved from http://www.larepublica.co/economia/colombia-ser%C3%ADa-segundo-productor-de-biocombustibles_23311

MANTILLA, A. (2003). Ecofisiología de la germinación de semillas. In Sánchez, A, Reigosa, M, & Pedrol, N (Eds.), La ecofisiología vegetal : una ciencia de síntesis (Vol. 1, pp. 901–922). Madrid: Ediciones Paraninfo.

NAKAGAWA, J. (1999). Vigor tests based on seedling performance. In Krzyzanowski, F., Vieira, R., & França, J. (Eds.), Seed vigor: definitions and tests (Vol. 1, pp. 1–24). Londrina, Brasil: Abrates.

OPENSHAW, K. (2000). A review of Jatropha curcas: an oil plant of unfulfilled promise. Biomass and Bioenergy, 19(1), 1–15. doi:10.1016/S0961-9534(00)00019-2

OIRSA. (2002). Producción de sustratos para viveros. OIRSA. Retrieved from http://www.croprotection.webs.upv.es/documentos/Compostaje/Sustratos-para-Viveros.pdf

PATEL, D., & SARAF, M. (2013). Influence of soil ameliorants and microflora on induction of antioxidant enzymes and growth promotion of Jatropha curcas L. under saline condition. European Journal of Soil Biology, 55(0), 47–54. doi:10.1016/j.ejsobi.2012.12.004

PEDRAZA S. ERIK, & CAYÓN S. D. (2010). Caracterización morfofisiológica de Jatropha curcas L. variedad Brasil cultivada en dos zonas de Colombia. Acta Agronómica, 59(1), 30–36.

PIRANEQUE, N, AGUIRRE, S, & MENJIVAR, J. (2007). Evolución del contenido de elementos nutrientes en suelos cultivados con cebolla de bulbo. Acta Agronómica, 56(1), 37–42.

POWELL, ALISON, & MATTHEWS, STAN. (2005). Towards the validation of the controlled deterioration vigour test for small seeded vegetables. Seed Testing International, 129, 21–24.

RÍOS CAMEY, J. (2012). Caracterización y germinación de semillas silvestres de Jatropha curcas l. colectadas en diferentes municipios del estado de Chiapas. (Seminario de posgrado). Universidad Autónoma de Nuevo León, Facultad de Ciencias Forestales, Nuevo León. Retrieved from http://www.fcf.uanl.mx/sites/default/files/files/26_%202%C2%B0%20Nivel%20Juan%20Manuel%20R%C3%ADos%20Camey.pdf

RODRÍGUEZ-ACOSTA, M., VEGA-FLORES, K., GANTE-CABRERA, D., HUGO, V., & JIMÉNEZ-RAMÍREZ, J. (2009). Distribución del genero Jatropha L. (Euphorbiaceae) en el estado de Puebla, México. Polibotánica, (28), 37–48.

RUCOBA GARCÍA, A., MUNGUÍA GIL, A., & SARMIENTO FRANCO, F. (2013). Entre la Jatropha y la pobreza: reflexiones sobre la producción de agrocombustibles en tierras de temporal en Yucatán. Estudios Sociales (Hermosillo, Son.), 21(41), 115–141.

SALINAS, A. R., YOLDJIAN, A. M., CRAVIOTTO, R. M., & BISARO, V. (2001). Vigor tests and physiological quality of soybean seeds. Pesquisa Agropecuária Brasileira, 36(2), 371–379. doi:10.1590/S0100-204X2001000200022

SINGH, B., SINGH, K., REJESHWAR RAO, G., CHIKARA, J., KUMAR, D., MISHRA, D. K., TULI, R. (2013). Agro-technology of Jatropha curcas for diverse environmental conditions in India. Biomass and Bioenergy, 48(0), 191–202. doi:10.1016/j.biombioe.2012.11.025

SOTOLONGO PÉREZ, J., DÍAZ GARCÍA, A., MONTES DE OCA LÓPEZ, S., GARCÍA PAVÓN, S., DEL VALLE ATALA, Y., & BEATON DELGADO, P. (2007). Potencialidades energéticas y medioambientales del árbol Jatropha curcas L en las condiciones edafoclimáticas de la región semiárida de la provincia de Guantánamo. Tecnología Química, 27(2), 76–82.

TEKRONY, D. M. (1995). Seed vigour testing: contributions to a seminar. Conference proceedings presented at the Seed vigour testing: contributions to a seminar. Zurich : International Seed Testing Association, Zurich. Retrieved from http://library.wur.nl/WebQuery/clc/910549